

# Longfin Smelt Risk Assessment Matrix (LSRAM)

REVISED October 30, 2008

	December	January	February	March	April	May	June/July
Life Stage(s) Present in or near the Delta	Adults, Juveniles, Eggs and some Larvae	Adults, Age-1 Juveniles, Eggs and Larvae	Adults, Age-1 Juveniles, Eggs and Larvae	Few Adults and Age-1 Juveniles; Eggs, Larvae and few Age-0 Juveniles	Few Eggs; Larvae and Age-0 Juveniles	Larvae and Age-0 Juveniles	Few Larvae; Age-0 Juveniles
Previous Two Year's Fall Midwater Trawl Indices, <b>Concern Level (1)</b>	Index below 240 for one or both years	Index below 240 for one or both years	Index below 240 for one or both years	Index below 240 for one or both years	Index below 240 for one or both years	Index below 240 for one or both years	Index below 240 for one or both years
Risk of Entrainment, <b>Concern Level (2)</b>	Increasing as X2 moves upstream of Chipps Island; reduced if Sac R. flows $\geq 55k$ cfs, SJR $\geq 8k$ cfs	Increasing as X2 moves upstream of Chipps Island; reduced if Sac R. flows $\geq 55k$ cfs, SJR $\geq 8k$ cfs	Increasing as X2 moves upstream of Chipps Island; reduced if Sac R. flows $\geq 55k$ cfs, SJR $\geq 8k$ cfs	Increasing as X2 moves upstream of Chipps Island; reduced if Sac R. flows $\geq 55k$ cfs, SJR $\geq 8k$ cfs	Increasing as X2 moves upstream of Chipps Island; reduced if Sac R. flows $\geq 55k$ cfs, SJR $\geq 8k$ cfs	Increasing as X2 moves upstream of Chipps Island and mean delta-wide temps $< 18^{\circ}C$ and south delta temps below $21.5^{\circ}C$ (a)	Increasing as X2 moves upstream of Chipps Island and mean delta-wide temps $< 18^{\circ}C$ and south delta temps are below $21.5^{\circ}C$
Adults present as determined by FMWT, Bay Study, <b>Concern Level and Trigger (3)</b>	Presence of 8 or more Adults ( $\geq 80mm$ ) east or south of Jersey Point	Presence of Adults $\geq 80mm$	Presence of Adults $\geq 80mm$				
Distribution, <b>Concern Level and Trigger (4)</b>	See footnote #4	See footnote #4	See footnote #4	See footnote #4 or negative 20mm centroid	Negative 20mm centroid (a)	Negative 20mm centroid (a)	Negative 20mm centroid
Salvage, <b>Concern Level and Trigger (5)</b>	Adult	Adult or Juvenile	Adult or Juvenile	If salvage is above zero	If salvage is above zero (a)	If salvage is above zero(a)	If salvage is above zero

	December	January	February	March	April	May	June/July
Tools for Change (6)							
Export reduction at one or both facilities	X	X	X	X	X	X	X
Change in barrier operations						X	X
Change in Sacramento River flows	X	X	X	X	X	x	x
Change in San Joaquin River flows	X	X	X	X	X	X	X
Change position of cross channel gates	X	X	X	X	X	X	X

(a) Actions in response to triggers suspended when the Vernalis Adaptive Management Plan is being implemented (31 days, typically in mid-April to mid-May).

## Longfin Smelt Risk Assessment Matrix Footnotes

Initiation of Smelt Work Group consideration of longfin smelt data: *Commencing on or after December 1, the Smelt Work Group will convene to discuss fish distribution and hydrodynamic data in preparation to make recommendations to the Department in the event a trigger it tripped.*

- 1 Abundance: Concern increases with declining Fall Midwater Trawl (FMWT) abundance indices for longfin smelt. Concern evaluation uses FMWT longfin smelt total indices (all ages) from the two-years previous to the calendar year of the larva/juvenile loss risk being evaluated (e.g., in 2008, the concern index would be FMWT 2006 and 2007 LFS indices). High concern exists when one or both previous indices are below the **critical concern index of 240** (the approximate index value at the lower limit of the 1988-2000 outflow-abundance relationship, Figure 1). *No actions are triggered by one or more indices below 240.* For recovery, indices at or above the 1988-2000 regression line are targeted ( $\text{Log}_{10} \text{Abundance} = 1.1224 * (\text{Log}_{10} \text{Outflow}) - 2.0045$ ).

Fall Midwater Trawl data are located at: <http://www.delta.dfg.ca.gov/data/mwt/>

- 2 Risk of Entrainment: Concern increases the farther X2 is located above river kilometer 70 during winter and spring and abates during periods of high outflow. *No actions are triggered by the location of X2.* We hypothesize that the location of X2 approximates where pre-spawning adults congregate and influences the distance they migrate into the Delta to spawn, and thus their vulnerability to entrainment in south Delta exports, as well as that of their offspring. Salvage of longfin smelt is highest in “dry years” (Sommer et al 1997). The highest and most consistent salvage of adult longfin smelt occurs when X2 is upstream of river kilometer (rkm) 70, and little salvage occurs when X2 is below 60 rkm (Figure 2). Sacramento River flow (3-day running average) of 80,000 cfs or greater pushes X2 well below rkm 60 (Kimmerer and Monismith 1993), moving water conditions suitable for longfin smelt spawning downstream of the Delta and transporting larvae downstream, away from the Delta as well (Baxter 1999, Dege and Brown 2004). Longfin smelt spawn in winter when water temperature is below 16°C and declining into 13-15°C range (Figure 3). These temperature relations were derived from plotting catches of yolk-sac larvae on water temperature measurements, both of which were taken by the Bay Study field crews at western Delta locations 535, 736 and 837, 1980-1989 (Figure 4). Larvae are typically present in colder temperatures and few early stage larvae continue to be present after water temperatures surpass 16.5°C in spring. Young juveniles avoid temperatures > 21.5°C and are rarely caught at temperatures over 22°C (Figure 5).

Critical thermal maxima for longfin smelt is unknown.

- 3 Adults in the Delta: Concern level increases when adult longfin smelt are found in the Delta by either the DFG Fall Midwater Trawl or the Bay Study Survey. We assume that adult longfin smelt ( $\geq 80$  mm FL) move into the Delta when spawning is eminent (see Nobriga and Castillo 2008), so identification of “spawning stage” is of secondary importance for concern level and spawning stage information will not be requested. The adult spawning stage is determined from longfin smelt ( $\geq 80$  mm FL) captured by one of the trawl surveys and/or

one of the salvage facilities. A stage greater than or equal to 4 indicates female longfin smelt are ripe and ready to spawn or have already spawned (following Mager 1996 for delta smelt).

- 4 Distribution of adults (December through February): Concern level increases with the number of adult longfin smelt ( $\geq 80$  mm FL, whether spent or not) collected within the Delta east or south of Jersey Point in the San Joaquin River or in south Delta channels (Figure 4) AND as X2 moves east of rkm 70. These fish are presumed to be on their spawning migration and to have deposited eggs near their collection sites (see also footnote 5). Collection of adults east or south of Jersey Point or in south Delta channels is a rare event and not statistically related to salvage; nonetheless, the following trawl catches of adults in December will **trigger action**: 1) catch of 8 or more adults from Fall Midwater Trawl stations south and east of Jersey Point, San Joaquin River (3% occurrence; n=38 yrs); or 2) catch of 8 or more adults from Bay Study stations south and east of Jersey Point, San Joaquin River (0% occurrence; n=14 yrs). Adult in-Delta distribution information is obtained from several monitoring surveys: the Fall Midwater Trawl in December, the Bay Study otter and midwater trawls in December, January and February, and the Spring Kodiak Trawl Survey in January and February. The Spring Kodiak Trawl does not effectively capture adult longfin smelt, but does detect them. The Chipps Island Trawl Survey (fixed location sampling at rkm 75) catches adults migrating upstream to stage and spawn, and can provide information on when and how many adult longfin smelt are entering or near the Delta. The December-February concern increases when adult longfin smelt ( $\geq 80$  mm FL), indicating that spawning may have occurred in the area, are detected east or south of Jersey point in the San Joaquin River or south Delta channels (Figure 4); however risk is substantially reduced when Sacramento River flows at Rio Vista surpass 55,000 cfs in a 3-day running average or those of the San Joaquin River at Vernalis surpass 8,000 cfs in a 3-day running average, and remains low until Rio Vista flows drop below 40,000 cfs or Vernalis flows drop below 8,000 for a 3-day running average, whichever occurred to reduce risk (see Figure 2).

Larvae and small juveniles (January-June): Sampling will commence in the first two weeks of January with a standard egg and larva net possessing 500 micron mesh and sample (a single tow) every 2 weeks at a subset of 20mm survey stations though the first 2 weeks in March (Figure 6); in mid-March sampling will switch to the 20mm Survey net and protocol, and continue into July. January through April concern increases and **action is triggered** if during any single survey longfin smelt larvae ( $< 20$  mm FL) or juveniles are captured at 6 or more of the 12 Smelt Larva Survey stations located east or south of Jersey Point or in south Delta channels: 809, 812, 815, 901, 902, 906, 910, 912, 914, 915, 918, 919 (Figure 6). The level of response is determined by the distribution of larvae and juveniles within the system (see for example [http://www.delta.dfg.ca.gov/data/20mm/CPUE\\_Map3.asp](http://www.delta.dfg.ca.gov/data/20mm/CPUE_Map3.asp) for longfin smelt; Figure 7). In particular, as the Smelt Larva Survey or 20mm Survey longfin smelt centroid moves toward zero from the west, concern increases and becomes very high as the centroid reaches zero or moves east of zero. If Sacramento River flow at Rio Vista surpasses 55,000 cfs or the San Joaquin River flow at Vernalis surpasses 8,000 cfs in a 3-day running average, concern abates and remains low until Rio Vista flow drops below

40,000 cfs or Vernalis flow drops below 8,000 for a 3-day running average (whichever relaxed the risk), and adults, larvae or juveniles are again found east or south of Jersey Point.

The 20-mm Survey centroid is calculated by multiplying the observed smelt station CPUE by a distance parameter in km from the confluence. The summed result (summed over a survey) is divided by the survey CPUE which gives the survey centroid position (see Figure 7 and [http://www.delta.dfg.ca.gov/data/20mm/CPUE\\_Map3.asp](http://www.delta.dfg.ca.gov/data/20mm/CPUE_Map3.asp), selecting longfin smelt).

5. **Salvage:** the adult **salvage trigger** for December is initiated by combined SWP and CVP cumulative salvage surpassing 24 adults (15%, n=26 yrs). In addition, during December and subsequent months the level of concern increases as the ratio of total longfin smelt salvage (December-March, all ages except larva) to the previous FMWT abundance index (all ages) increases past the 50<sup>th</sup> percentile (Figure 8) and concern becomes very high if the ratio exceeds the 70<sup>th</sup> percentile of those observed during 1980-2007 period (see Figure 8 for more explanation of the calculation). If Sacramento River at Rio Vista flow surpasses 55,000 cfs or San Joaquin River flow at Vernalis surpasses 8,000 cfs in a 3-day running average concern abates and remains low until Rio Vista flow drops below 40,000 cfs or Vernalis flow drops below 5,000 cfs for a 3-day running average (whichever reduced concern), and longfin smelt begin to be salvaged once again.

6. The tools for change are actions that the Smelt Working Group can recommend to help protect longfin smelt. Recommendations on negative or reversed Old and Middle River flows can be made; such reverse flows are directly related to longfin smelt salvage. Exports may be reduced at one or both of the south Delta export facilities and a proposed level and duration of the reduction would be recommended by the Smelt Working Group. Barrier operations can be changed to allow more or less water to move directly through Old River to the pumps; San Joaquin River water moving directly to the pumps reduces the volume drawn south through the Delta. Changes in Sacramento River flows affect the position of X2, potentially adult spawning locations, and the flows available for downstream transport of larvae and juveniles out of the Delta. Changes in San Joaquin River flows, in concert with export pumping, directly influence the magnitude and direction of Old and Middle River flows, which are related to longfin smelt salvage. Cross channel gate operations influence how much Sacramento River water moves directly south through the Delta, and can potentially affect the transport direction of larval and young juvenile longfin smelt.

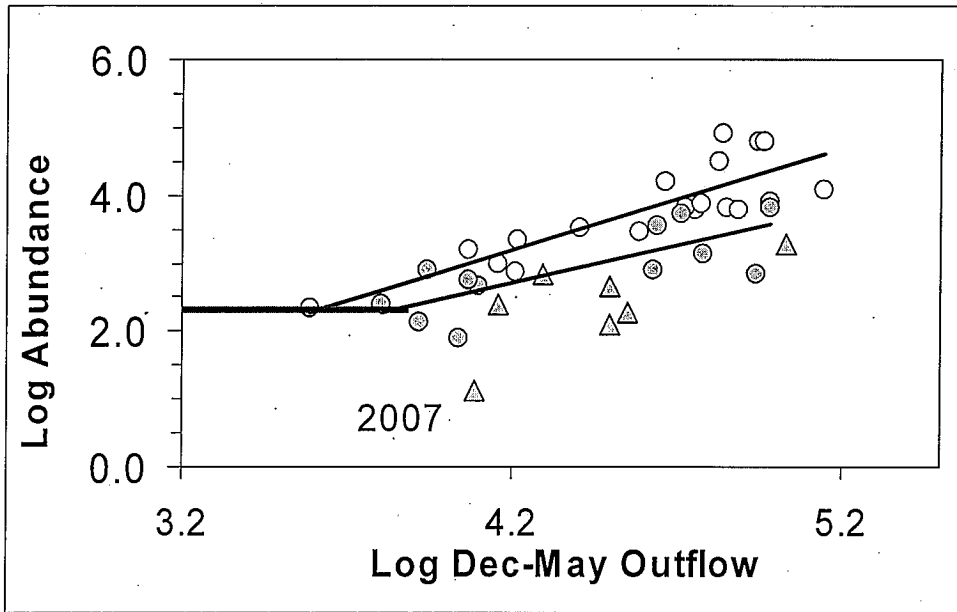


Figure 1. Longfin smelt outflow abundance relationships where Fall Midwater Trawl total longfin smelt abundance indices (1967-2007,  $\log_{10}$  transformed) are plotted against mean December through May outflow at Chipps Island (cfs,  $\log_{10}$  transformed). The red line represents the  $\log_{10}$  transformed critical concern index of 240. The two relationships plotted are: 1967-1987 before the overbite clam *Corbula amurensis* became extremely abundant (open circles); and, 1988-2000, the period subsequent to *Corbula amurensis* (filled circles). The equation for the 1988-2000 relationship is  $\text{Log}_{10} \text{ Abundance} = 1.1224 * (\text{Log}_{10} \text{ Outflow}) - 2.0045$ . Outflow-abundance points for the POD years 2001-2007 are represented by filled triangles and are not part of either relationship.

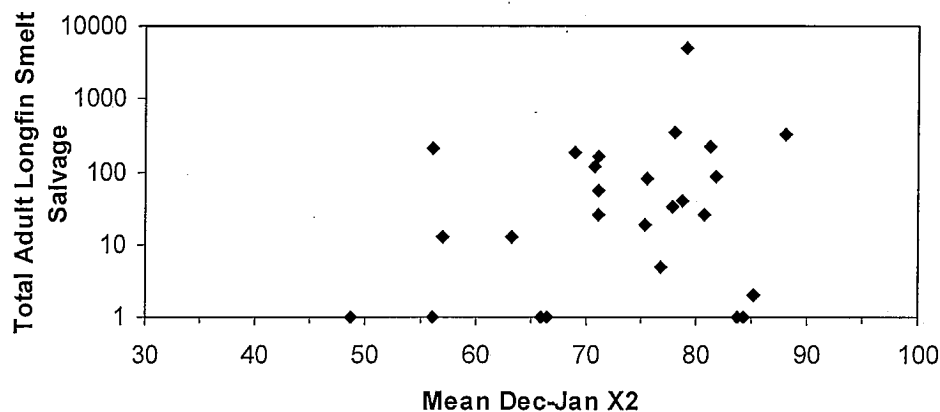


Figure 2. Total adult longfin smelt salvage (Dec-Feb) from the State Water Project and the Central Valley Project combined (+1 for plotting on log scale [y-axis]) as a function of mean daily X2 location for December and January (Chris Enright, DWR data) for 1982-2007. This time range includes a period (1982-1992) before both species identification and length measurements were sufficient to develop complete age-specific salvage. All December through February longfin smelt counts where no fish were measured were assumed to be all adults. Lengths used to classify measured fish into age groups follow Baxter (1999). Delta outflow requirements for steady state X2 at rkm 60 is 43,000 cfs, at rkm 70 is 18,000 cfs and at rkm 80 is 7500 cfs; less outflow is required if X2 is allowed to vary about the target river kilometer location (Kimmerer and Monismith 1993).

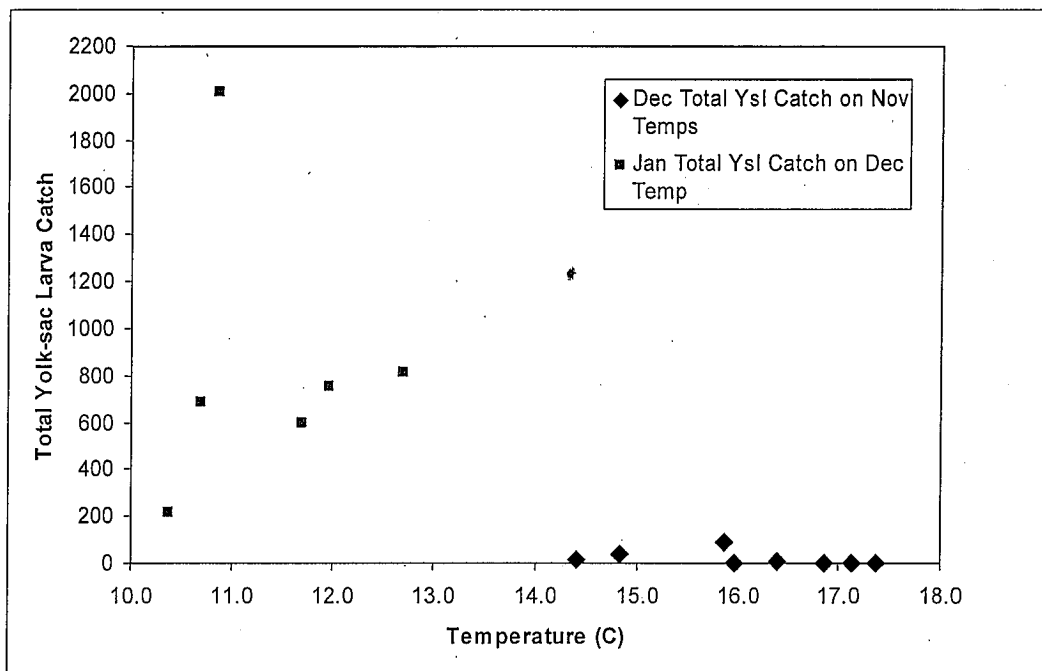


Figure 3. Total catch of longfin smelt yolk-sac larvae (YSL) by month and year for December and January plotted against average bottom temperature measured the previous month by the San Francisco Bay Study at stations 535, 736 and 837 located in the western Delta (1981-1988). This assumes longfin smelt incubation takes about 25 days at 10°C (Moulton 1970); warmer temperatures should reduce incubation time, so larva numbers were plotted against temperatures from the previous month. Temperatures displayed were averaged measures taken at the bottom of the water column from Bay Study. The stations selected were presumably near where longfin smelt spawned.

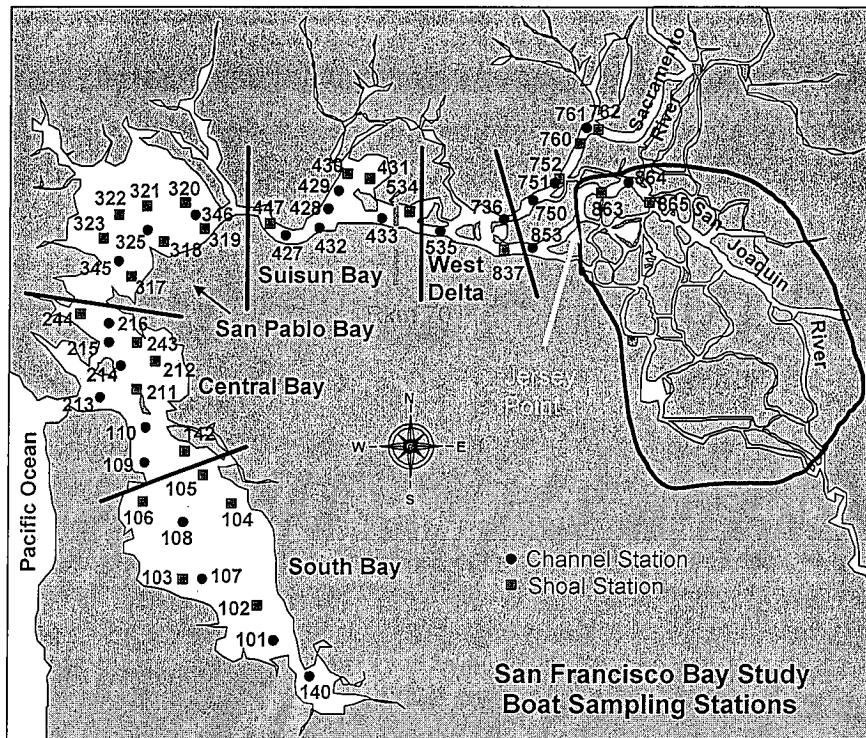


Figure 4. San Francisco Bay Study sampling station map showing the location of Jersey Point (yellow arrow) and region of concern for longfin smelt east and south of Jersey Point (black line delimited). River kilometer 70, located in Suisun Bay is depicted in light blue.

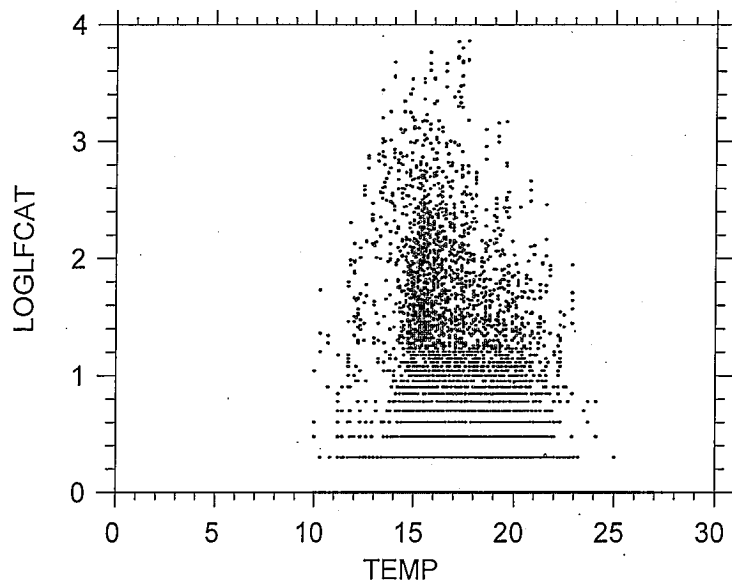


Figure 5. Longfin smelt (larva and juveniles <40 mm FL) temperature (°C) distribution weighted by  $\text{Log}_{10}(\text{Total Catch}+1)$  for all valid 20mm Survey samples, 1995-2007. The upper 95<sup>th</sup> percentile of the temperature distribution is 21.2 °C (99<sup>th</sup> = 22.3°C). The 20mm Survey initiates sampling in mid-March, after the annual water temperature minima.

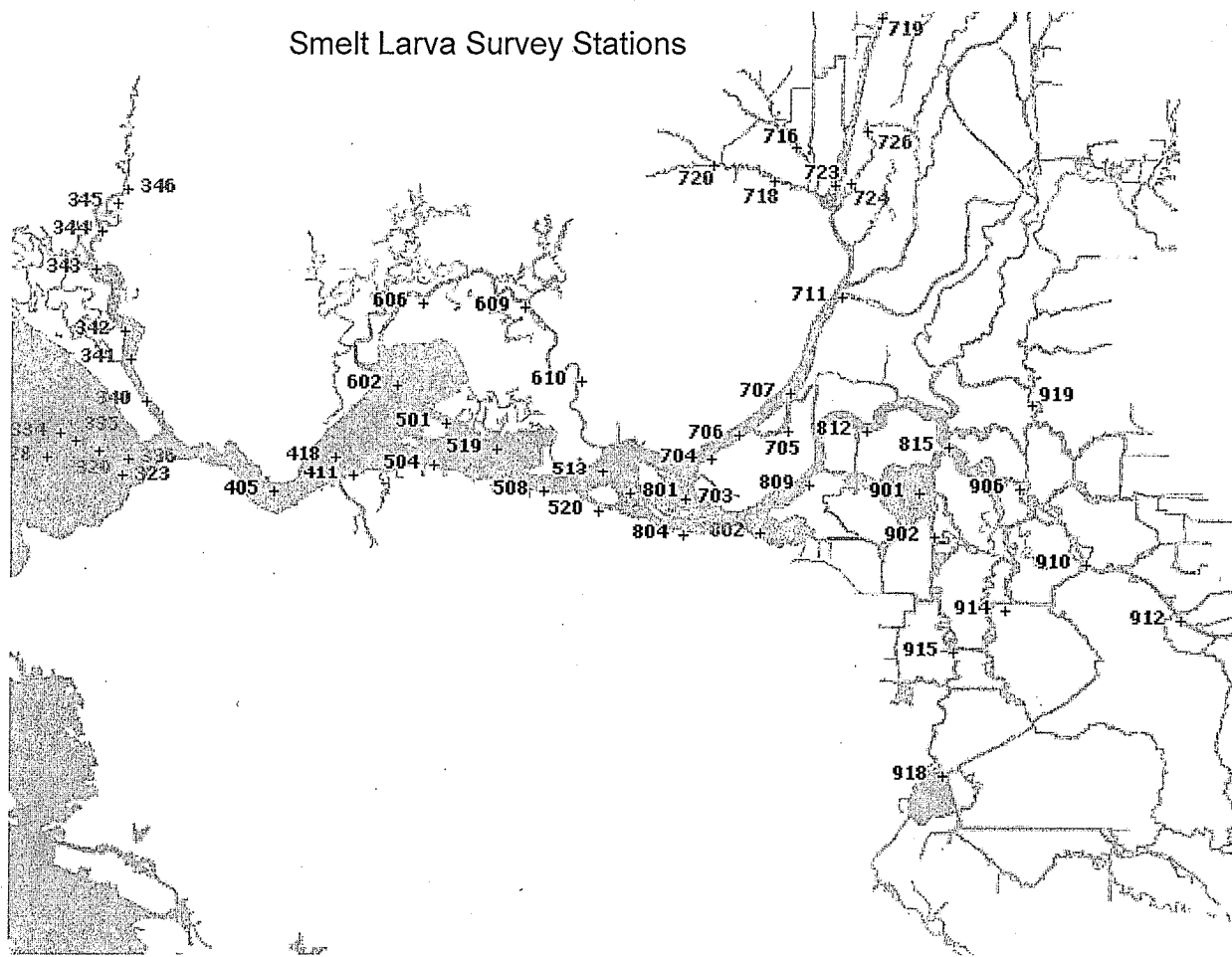


Figure 6. Smelt Larva Survey Map. Sampling begins in the first two weeks in January and continues every other week until the middle of March.

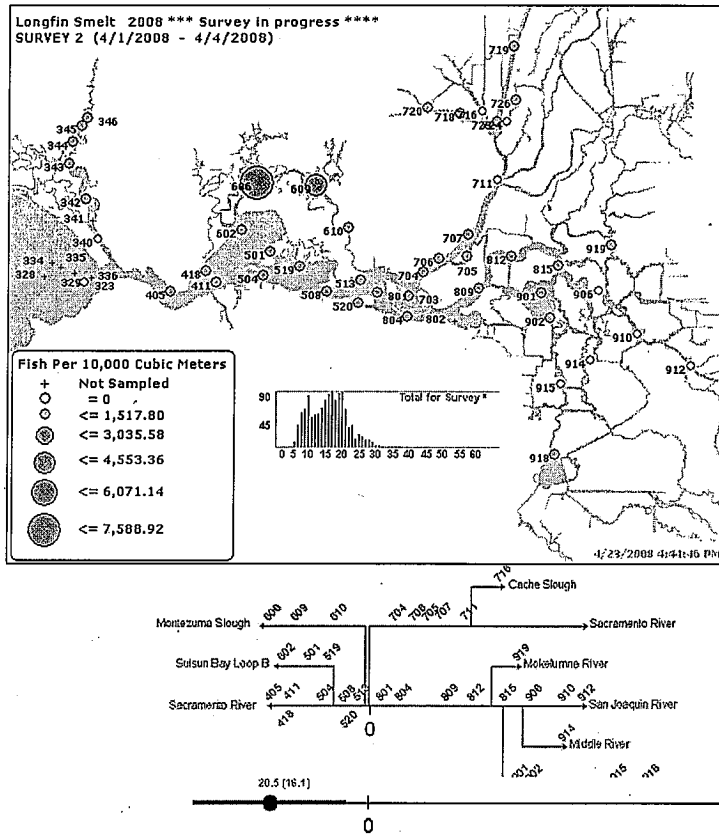


Figure 7. Longfin smelt distribution from 20mm Survey number 2, April 1-4, 2008 ([http://www.delta.dfg.ca.gov/data/20mm/CPUE\\_Map3.asp#GraphImage](http://www.delta.dfg.ca.gov/data/20mm/CPUE_Map3.asp#GraphImage)). Distribution maps above a schematic representation of Delta and upper Estuary channels with stations positioned proportionally away from the confluence zero-point based on river kilometer distance. The blue dot and line in the bottom portion of the figure depict a catch-per-unit-effort weighted mean distribution or "centroid" and standard deviation. A favorable distribution includes a centroid well west of the confluence (as depicted) and few larvae captured east or south of Jersey Point in the San Joaquin River or south Delta channels.

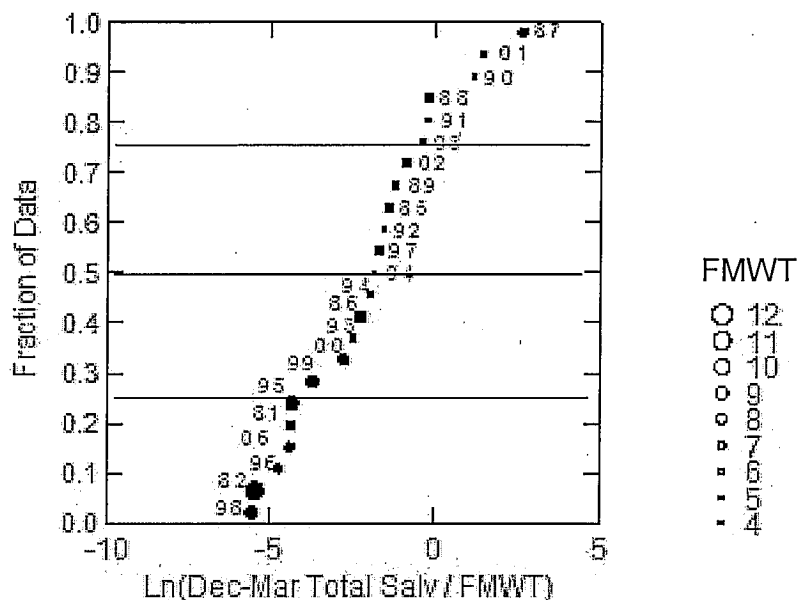


Figure 8. Quantile plot of natural-log transformed ratios of total winter (December through March) salvage of longfin smelt (both facilities and all ages except larvae) and the preceding Fall Midwater Trawl (FWMT) longfin smelt abundance index (all ages). Ratios above the 0.5 line constitute increasing levels of concern. Bubble size is proportional to the FMWT longfin smelt index and labeled with the year of the FMWT index.

The objective is to quantify a level of concern for longfin smelt salvaged during winter, based upon not only the number of fish salvaged, but also their overall abundance. The ratio quantifier reflects that when the abundance is low and salvage is high concern is high and conversely, when abundance is high and salvage is low that concern is low. The resulting quartiles were approximately: 25% = -4.330; 50% = -1.851; 75% = -0.366.

If we were to use this approach to calculate winter concern levels based on the median value, then all years above the 2004 point in the graph would have been years of concern. In other words, additional protections would have been recommended in years above the 2004 point.

The median, selected as the measure of concern, results in a salvage concern level calculated as:

$$\text{concern level} = \text{anti ln}(-1.851) * \text{FMWT total abundance index}$$

$$\text{where anti ln}(-1.851) = e^{-1.851}$$

## References Cited

- Baxter, R.D. 1999. Osmeridae. Pages 179-216 in J. Orsi, editor. Report on the 1980-1995 fish, shrimp and crab sampling in the San Francisco Estuary. Interagency Ecological Program for the Sacramento-San Joaquin Estuary. Technical Report 63. Vol.
- Dege, M. and L.R. Brown. 2004. Effect of outflow on spring and summertime distribution and abundance of larval and juvenile fishes in the upper San Francisco Estuary. American Fisheries Society Symposium 39:49-65.
- Dryfoos, R.L. 1965. The life history and ecology of the longfin smelt in Lake Washington. Ph.D. Dissertation. University of Washington, Tacoma WA, 229 pp. pp.
- Kimmerer, W. and S. Monismith. 1993. Appendix A. An Estimate of the historical position of 2 ppt salinity in the San Francisco Bay Estuary. An issue paper prepared for the fourth technical workshop on Salinity, Flows and Living Resources of the San Francisco Bay/Delta Estuary, August 1992. in J.R. Schubel, editor. Managing freshwater discharge to the San Francisco Bay/Sacramento-San Joaquin Delta Estuary: the scientific basis for an estuarine standard. San Francisco Estuary Project, San Francisco, California, USA.
- Mager RC. 1996. Gametogenesis, Reproduction and Artificial Propagation of Delta Smelt, *Hypomesus transpacificus*. [Dissertation] Davis: University of California, Davis. 115 pages. Published.
- Nobriga, M., and G. Castillo. 2008. Unraveling the mystery: where do delta smelt and longfin smelt spawn and how do they get there?, Sacramento, California. 11 pp plus graphics
- Sommer, T., R. Baxter, and B. Herbold. 1997. Resilience of splittail in the Sacramento-San Joaquin Estuary. Transactions of the American Fisheries Society 126:961-976.